Academy of Romanian Scientists
Journal of Knowledge Dynamics

The Impact of Artificial Intelligence on Economic Practice and Theory

Emil DINGA [1,2]
[1] Centre for Financial and Monetary Research „Victor Slăvescu", Romanian Academy House, Building West, Floor 5, Room 5315, Romania, ORCID 0000-0002-3750-3248.
[2] Academy of Romanian Scientists, Ilfov 3, sector 5, Bucharest, Romania
emildinga2004@gmail.com

Received: May 3, 2025
Revised: May 21, 2025
Accepted: May 31, 2025
Published: June25, 2025

Abstract: *The paper aims to examine two categories of impact that artificial intelligence (AI) can develop at the societal level: on the economic process and on economic theory. The impact on the economic process covers: productivity, management, training, production, and distribution. Impact on economic theory covers: utility, price, wage, unionization, factors (and function) of production, substitutability and complementarity of economic output, unemployment, rights and freedoms, and economic crises.*

Keywords: productivity; substitutability; wage; specialization; production function; tax.

Introduction

The impact of artificial intelligence (AI) on the economy (economic process, economic system, economic theory, praxeology in general) occurs in two ways: (a) the *indirect* way – through AI technology as a (neo)factor of production in the economic models in question, therefore, especially through the impact on economic theory and methodology; (b) the *direct* way – through the impact of AI on the pre-conditions and conditions for carrying out the economic action (activity) itself.

(a) indirect pathway

Economic action is an action based on efficiency, that is, on a ratio of minimizing effort (of all kinds) for an expected/given effect (of all categories). *Nota bene*: or vice-versa, a ratio of maximization of the effect for a calculated/given effort – of course, the careless journalistic expressions like "maximizing the effect and minimizing the effort" are unworkable, because they claim extremes, possibly optimizations, simultaneously according to two criteria (or objective-functions) contradictory to each other as kinematic direction. The indirect way of AI penetrating the economy essentially refers to the emergence of neo-factors of production – information, knowledge, as they are "captured" in technologies as such (e.g., fixed capital), in circulating capital (e.g., raw materials, energy), in production technology (black-box) or economic distribution, in economic management (including financial), that is, regarding all economic factors except the human individual himself. *Nota bene*: regarding the exception of the human factor from this (almost) generalized impact on the modelling of the production function in economic theory itself we will return below.

(b) direct pathway

The direct path of AI into the economy refers to the concepts, mechanisms, and, ultimately the models that economic theory proposes, considering the issues arising around the human factor – labour – as a result of AI. In what follows, we will only refer to the direct

How to cite
Dinga, E. (2025). The impact of artificial intelligence on economic practice and theory. *Journal of Knowledge Dynamics,* Vol. 2, No. 1, pp.05-18. https://doi.org/10.56082/jkd.2025.1.5 ISSN ONLINE 3061-2640

path of penetration (and influence) of AI on economic theory, on the one hand, and on economic activity, on the other.

Labour force and work

In the orthodox (or "traditional") way, labour force refers to a biological and intellectual potential of the human person to carry out an economic action/activity (of production or/and distribution of the economic product), for a certain period of time, in certain conditions and to certain standards of productivity and quality. Labour force is therefore credited with the potential to carry out certain operations, physical or intellectual, integrated in a given economic logic. The concept of labour force was (and, of course, is) considered as a specific carrier of work, since the objectification of labour force is represented by work.

[i] So, the definition of the concept of labour force, as potential, claims both a biological and an intellectual potential. For the continuation of the reasoning, we will introduce the concept and the term of artificial intelligence device (AID) to name a certain real entity, of a simultaneously physical and informational[ii] type that is involved, on its own, in a social process, in this case, an economic process. An AID cannot be a biological device,[iii] it is a technical/technological device, which means that a first component of the definition of labour force (biological determination) is not verified. Regarding the second component – intellectual potential – things are a bit more complicated. First of all, we will have to understand what is meant by the intellectual component or, more precisely, to define the concept of intellectual. In our opinion, intellectualism is a property assigned to awareness, that is, that property of a subject that allows it to have representations. By representation is meant a perception that does not "claim", for the purpose of perception, the presence *in actu* of the object targeted for perception. According to our current knowledge, only human being possesses the capacity of representation, that is, s/he has awareness. Presence *in actu* also allows the act of perception for living beings that do not have awareness. From a scientific point of view, we still do not know what awareness is, although, assuming awareness we can define consciousness as that culturally conditioned awareness. AIDs can, of course, perform these operations as well as (and usually much better than) the human person. We can say that a certain AID (for example, a robot, humanoid or not – obviously, the humanoid form is not relevant here, although it has certain advantages especially in the case of AID inter-action with human individuals, but not in other circumstances) constitutes a unit of labour force, analogous to the labour force represented by a person? We formulate the following considerations in this regard:

- the concept of *work* was, from the very beginning, anthropomorphized, in the sense that it referred to the general consumption of physical/biological and intellectual energy of a human person in performing of an economic or, as the case may be, non-economic task (for example, writing a article), regarding the fulfilment of a predetermined objective, more precisely, a purpose, either the own purpose of the human individual in question, or the purpose of a social group that includes that individual, or the purpose of another individual, for example of a employer of the individual considered (we specify that the purpose is to raise awareness of the finality). Obviously, such a definition is no longer possible with reference to AID.
- the place of the consumption of physical and intellectual energy of the individual must be replaced by exclusively material consumption (which includes energy, let us say, technical, physical wear of the hard components of the AID), respectively by the moral wear of the soft components of the DIA;
- the objective in fulfilment of which the AID effort is carried out no longer turns into a purpose, because the latter implies the awareness of the objective, a fact forbidden to AID by all the previous. AID may, of course, have objectives set by programming instructions, but it, in itself, has no purpose – although there is obviously purpose at the level of the person or group instrumentalizing that AID;
- therefore, according to all that has already been mentioned, in the case of the action/activity carried out by an AID, it is not about work. The bottom line is that we

either have to generalize the concept of work, or call AID activity something other than we call the work. My proposal is the following:

a) from a logical (definitional) point of view, AID has the nature of physical capital; indeed, it is an artefact, it is not intended for direct consumption, but for mediated consumption through the production of other products that are only intended for direct consumption. AID is not fully consumed in one cycle of economic activity, but participates in several such cycles, reducing its economic value through financial depreciation (either at the level of physical wear or at the level of moral wear);
b) in these circumstances, AID falls under the production factor called physical capital (not financial capital!), so it does not perform work;
c) in principle, AID is a (super)augmented form of physical/technological capital, i.e., it does not bring anything new from the perspective of the economic theory of labour force and work. As a result, there is no need to accept a new concept and find a new term for the economic activity carried out by AID, respectively by AI.
d) as is known, technical progress, as a neo-factor of production, is also currently considered in theoretical models (e.g., in Cobb-Douglas type production functions or in more complicated production functions, such as CES functions).

Hiring, contract

Based on the previously established, the entrepreneur will not hire the AID, but will simply purchase it as s/he does with any "individual" of physical capital – it does not matter the technological level of the respective conditions to change the typological framing of the AID in the set of factors of economic production. So, the concepts of hiring, contract and the like, which might cross our mind in connection with AID, are absolutely (not circumstantially) erroneous, since we are not dealing with a unity of labour force, but with a unity of physical capital. Of course, there are repercussions (which can be identified and measured) of the AID acquisition on the "real" labour force, i.e., on human persons: changes in wages/salaries, changes in contractual clauses, changes in the number of human vacancies, the number of unemployed, etc., but they refer, as we see, exclusively to human persons, not to AI units.

Wage/salary, tax, social contributions

In the same logic used above, it must be said that there is no question of the payment of salaries (we remember that we do not have a "work" contract with AID), respectively of the collection of tax or social contributions or of... contribution for health for the units of AID purchased and operated in the economic activity. As I said, AID units are physical capital in nature, not labour force in nature. If it cannot be a question of the salary granted to AID i.e., tax on the "income" generated by the AID or social contributions related to this "income", there is, however, the question of the income (more precisely, the profit) obtained by the entrepreneur who uses AID. In relation to this issue, we make the following considerations:

- considering the exponential increase in economic performance (more precisely, in the output of the production function) in the case of using AIDs, the question arises whether AI can lead to discussing the idea of an AI tax. Of course, AID, being of the nature of physical capital, has its own "income", as defined in standard (textbook) economic theory, namely interest – this is the typical case where physical capital is acquired with the help of financial capital that represents a loan contracted with the commercial banking system;
- however, the creation of AID represents a result to which the whole society contributes – from educational structures to scientific research structures, both public and private;
- the reproduction of AID, as physical capital used by the entrepreneur, is done through the depreciation of AID. But given the immediately preceding specification, society as a whole should benefit from a boost from users (and applicants) of AID, and this can be achieved by instituting a tax on the added value (or, better, profit) brought by AID within the function of production in which AID is a (new) factor of production;[iv]

- such a tax on AID could be called *AI-vignette* (AIV) and would represent a sub-unit coefficient applied to the monetary value of AID used in the production function in question;
- the justification (rationality) of introducing such a tax consists of, at least, the following:
  - AID is a species of augmented physical capital (if it can be said so), that is, it represents a distinct category of physical capital;
  - as augmented physical capital, AI/AID has a yield well above the average of ordinary physical capital, which leads to a particularly high total factor productivity (TFP – total factor productivity);
  - as I show below, this contribution of AID to the profit recorded by entrepreneurs is an effect of the effort of the entire society in creating AID, so the society must "take back" part of the merits due to it;
- of course, there is the crucial problem of defining AID, more precisely of establishing the difference between the species called AID and the genus called physical capital. In this regard, we advance the following suggestions:
  - I believe that the crucial criterion for defining an AID is its autonomy in relation to the external environment. Of course, autonomy is a result (or a characteristic) of the program inserted into AID but, once that program is inserted, the only thing that matters is the degree of autonomy with which the AID "behaves" in the environment in which it is programmed to operate;
  - of course, how to determine the degree of autonomy in operation is a technical (and logical) matter that I do not go into in the present report – I presume it is determinable and, in fact, determined, for a generic AID considered;
  - based on the above, it is now obvious that the size of the AI-vignette (AIV) coefficient must be proportional to the degree of functional autonomy of the AID. We propose the following calculation formula (with α_a^f the degree of functional autonomy of the AID was noted; with K_{AI}^v the coefficient of the AI-vignette was noted):

$$K_{AI}^v = \frac{P}{1 + e^{-\alpha_a^f}}$$

    which is a logistic function – accelerated at low values of the degree of autonomy but, after an inflection point, decelerated to the horizontal asymptote with the value of P. In relation to the parameter P, I specify that its value is the value of the average rate of personal income taxation. The justification for this proposal consists of the following:

- the "taxation" of the profit brought by the production factor subsumed under the concept of artificial intelligence (in this case, AID) must align with the rationality with which the personal income of labour force is taxed, because AI (respectively AID) is conceptually closer to labour force than ordinary physical capital, as a result of the functional autonomy[v] of AI/AID;
- since, as previously shown, the creation of the AID is an effect of the effort of the whole society, the value of P must represent an average, [vi] at the national level, of the personal income tax rate related to the labor force. [vii]

Figure 1 suggests the curve of $K_{AI}^v = h(\alpha_a^f)$ function, and Figure 2 shows how the AI-vignette is formed (*Nota bene*: with π_{AID} is noted the marginal profit brought by AID use).

Additional comment

- the accelerated increase in the tax rate of the profit generated by AID, up to the inflection point, is justified by the fact that the use of AID in the production function leads to increasing returns; [viii]
- the decelerated increase, after the inflection point, of the tax rate on the profit generated by AID, is justified by the fact that, for reasons of complementarity[ix] of production factors, the share of AID in the total of production factors cannot increase indefinitely, so it is not fair that the tax rate continues to increase rapidly.

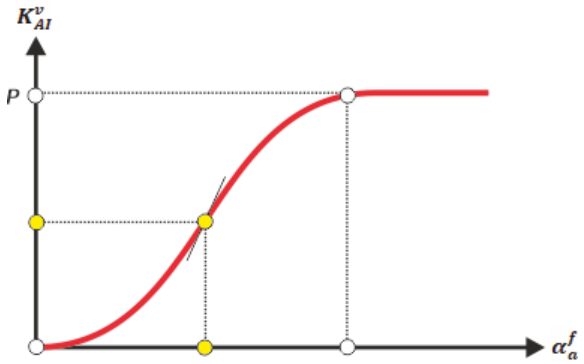

Figure 1. Logistic curve of AID taxation
(Source: Author's research)

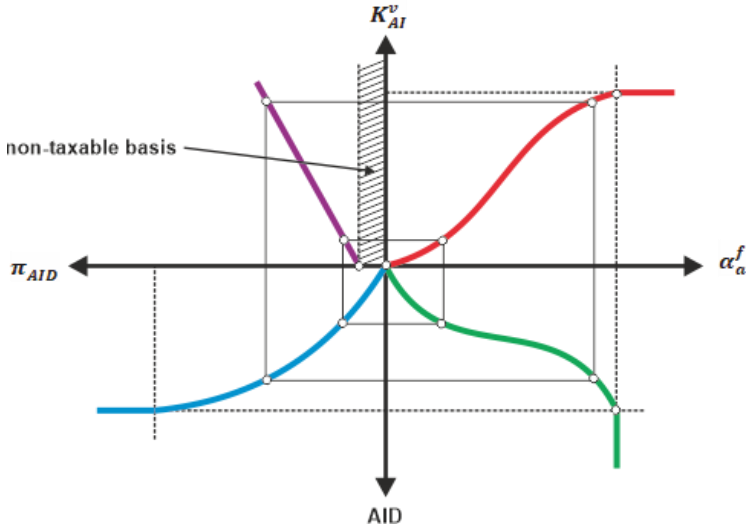

Figure 2. Forming AI-vignette value
(Source: Author's research)

Unemployment, employment

In relation to AID we cannot, therefore, talk about unemployment or employment either, although (as I have shown earlier) the impact of the purchase of AID units on unemployment/employment, wages, etc., and other phenomena or events associated with human persons, exists. Economic models can capture such effects, and they are relevant to both the microeconomic and macroeconomic levels (e.g., for public policy). However, with regard to the human workforce, it makes sense to talk about unemployment and employment respectively. The following considerations may be of interest here:

- the introduction and expansion of AI in economic activities and processes has a „J"-curve effect on employment (and, through the 'difference to 1', on unemployment among the labour force). The „J" curve (*Brynjolfsson et al., 2021*) means that, in the short run, there are labour substitutions with AID (which produces increased unemployment of the labour force and, by "mirroring", reduced employment) but, in the medium run, and especially, in the long term, there is a return to the previous

level of employment and, with a high probability, to an increase axiology in the level of employment;

- the previously mentioned phenomena are accompanied, for obvious reasons, by structural changes in employment, respectively unemployment, manifesting a tendency to direct the newly employed towards the infrastructure, so to speak, of AI: programming, maintenance, research, management and the like, i.e., to occupations that are located both upstream and downstream of the introduction of AID in economic activities/processes;
- we formulate the following conjecture in this matter: *the increase in the employment (properly: the reduction of unemployment) of the labour force, after the manifestation of the worsening of the situation in the short term as a result of the implementation of AI, is faster than the worsening trend*. Of course, being a conjecture, it must first be demonstrated theoretically, then empirically/factually tested, and finally used as a predictor to assess labour market dynamics under the impact of large-scale AI implementation;
- we complete the above conjecture with the following: *a multiplier* (which, like any other multiplier in the economy, has a marginal nature and a super unit numerical value) *of the introduction of AI (respectively, AID) necessarily operates on employment*.

We specify, once more, that, relative to AID, we cannot talk about employment, because AIDs are of the nature of physical capital. In relation to AID, one can speak, like any physical production capacity, of underutilization – for example, if the demand for specific goods and services decreases, the degree of utilization of AID will also decrease and, of course, a reduction is also possible of employment (i.e., the degree of "utilization" of labour). To formalize the mentioned conjecture, Figure 3 provides a synoptic picture of the functioning of the AI/AID multiplier (with γ_{AID} the degree of endowment of economic activity with AID was noted; with γ_o the degree of employment; with m^o_{AID} was noted the AI multiplier) where:

$$m^o_{AID} = \frac{\Delta\gamma_o}{\Delta\gamma_{AID}}$$

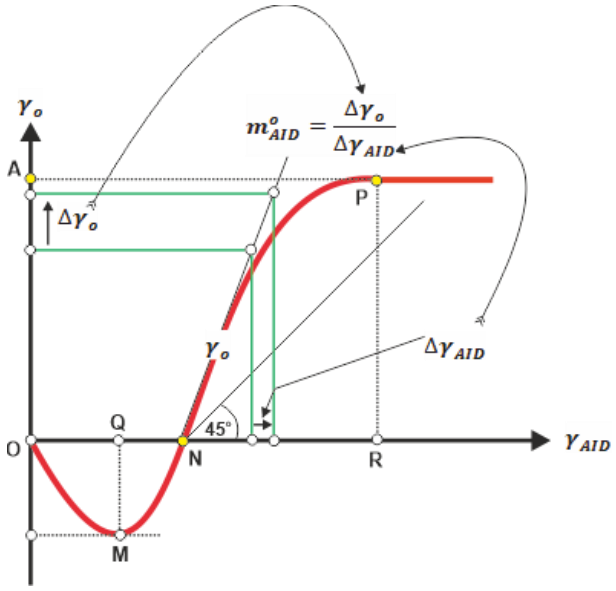

Figure 3. The multiplier of AI/DIA introduction on unemployment/employment in the economy
(Source: Author's research)

Discussion

- the AI multiplier on employment is a marginal quantity (ratio of two absolute variations);
- on the OM portion there is a decrease in employment (therefore, an increase in unemployment), as a result of the increase in the use of AID from zero (point O) to Q – the value of M is the maximum point of unemployment generated by the use of AID;
- the continued increase in the use of AID from Q to N leads to an accelerated reduction in unemployment (hence, to an accelerated increase in employment) from point M to point N (*Nota bene*: to be more precise, on the portion MN the employment lost on the portion OM is recovered);
- point N represents the very point of inflection of the m_{AID}^{o} curve, from that point the increase in employment as a result of the continued increase in the use of AID is decelerated (the curve is concave); this decelerated increase in employment continues until the asymptote A is reached, which occurs as utilization increases to the value R;
- it is noted that after the inflection point N the slope of the concave curve of the AI multiplier on employment is greater than 1, so a one unit increase in AID utilization will lead to a more than one unit increase in labour force employment.

Trade unions, employers' associations

This point is a bit more... extravagant. He tries to return to the problem of an intra-network communication of AIDs among themselves and, as a result, the possibility of organizing these AID units, including in the form of "community" structures, of the trade union or employer association type, as the case may be (there may be businesses that are run by robots who, as "managers", have to decide, for example, on the acquisition or de-activation of AID units). The problem is that, at least in the current (standard) understanding, AID units are not subjects of law, so they are not subjects of rights and obligations. *Nota bene*: only human persons can be subjects of law, namely only by virtue of their free will. Of course, with regard to labour force (i.e., the human factor of production in economic production functions), trade union or employer associations issues remain valid. However, in relation to the possibility that AID can agglutinate in structures that exclude observability by humans, certain aspects must be mentioned:

- it is, of course, obvious that the AID will not be programmed to form associations with each other. However, programming errors or subtle "gateways" through which AIDs can self-program in this direction are possible. In other words, we consider this possibility to be one that lies in programming errors, and programming is never infallible;
- probably, the previous situation can be annihilated, also by programming, in the following way: the introduction of a "program line" which, explicitly, this time, prohibits association of any kind between AIDs – by association it will probably have to be defined a way of making concerted decisions (*Nota bene*: what, in the case of humans, is called collusion).

Production/distribution/consumption

In terms of production, AI will gradually lead to its de-concentration and decentralization – people will be able to produce at home (at least) the products of strict necessity and that do not require special professional specialization and technological endowment. This will lead to a de-standardization (or, equivalently, to a heightened customization – economic theory calls this differentiation) of products, whether goods or services, auspicious trend for increasing and maintaining self-esteem. Of course, the possibility of purchasing goods from concentrated production/distribution centres – enterprises, shops – will be maintained, but, even in this last case, the degree of customization of the respective products will increase strongly.

In terms of distribution, AI will increasingly allow the sale of products (especially durable ones) to be replaced by their rental, i.e., their use for a certain period (which may or may not coincide with their lifetime) and then the restitution to the owner, who will proceed accordingly from an ecological point of view (reconditioning, ecological neutralization, scrapping, etc.), respectively economically (re-introduction into the economic circuit). Relinquishing ownership of durable goods will be a necessary consequence of the expansion of AI, respectively the use of AID, with beneficial consequences for all three "parties": producer, buyer, environment.

Specialization vs. de-specialization

An interesting phenomenon that can be inferred from the "anatomy and physiology" of AI is that of the professional specialization of the human person. I believe that a process of de-specialization of the labour force (of the economically active human person) will also necessarily (that is, inevitably) occur, because specialization (including super-specialization) will be transferred to (will be taken over by) AID. In this way, Marx's "prophecy" will be fulfilled according to which the human person will become a "generalist", that is, s/he will be able to deal, alternatively, with various professions or occupations, with the same competence, without being tied to a certain narrow specialization. Although Marx predicted this trend in a speculative and inferential way, AI today provides the infrastructure for such a phenomenon to actually occur. So, AIDs will become more and more specialized, while the human person will become more and more generalist. *Nota bene*: of course, there is an implicit assumption at work here, namely that there is a competence of a general nature, which does not need to be deep, as in the case of specialization, but rather extensive, that is, it must develop horizontally, not vertically. The reverse is the case with AID: competence is developed vertically rather than horizontally – however, the horizontal competence, so to speak, of AI, is achieved through the network of AID.

As kinematics, AID specialization is faster than labor force de-specialization (Mishra et al., 2023)). We believe that both processes are necessary processes, that is, they will occur inevitably, especially since the task of AID programming will gradually be taken over by AID itself, thus acquiring an automatic form.[x]

Productivity

From the point of view of economic theory, the production function allows the calculation of the apparent productivity of each factor of production involved – it is called apparent productivity because the entire output of the production function is distributed over a single factor of production. Of course, a so-called total factor productivity is also calculated, which considers all the factors of production. The use of AID has the undoubted effect of increasing (possibly) exponentially the output of the production function. So, just as the productivity (or return) of physical capital was calculated until now, this indicator will, from now on, also include AID which, as I have shown before, must be considered of the nature of physical capital. It follows that the apparent productivity of labor (of labour force, to be exact) will increase greatly, which, under the conditions of the massive use of AI, has little economic significance. In this context, my opinion on this matter can be summarized as follows:

- the concept of labor productivity, understood as the apparent productivity "allocated" to the workforce, will have to be replaced by the concept of *depreciable factor productivity* - DFP (which refers to labor and physical capital) and which will also have to replace the current concept of total factor productivity (total factor productivity – TFP);
- the question arises whether there is (or should be) a threshold for equipping the economic enterprise with AID, above which this new concept of productivity can be introduced. I believe that the following reasonings may be useful:
  - the introduction of AID in the fixed capital structure does not leave "untouched" the classical elements of fixed capital, because structural and functional

compatibilities must be created between AID and the other fixed capital elements (let's call the latter: SFC – standard fixed capital);

- this means that there is some mandatory refinement of the SFC to ensure the most effective use of AID, and this refinement includes refinements (e.g., interfaces between AID and SFC) of SFC or even intermediate stages of transition from SFC to AID;
- I conjecture that the introduction of AID will lead to the emergence, between AID and SFC, of an osmotic belt, in which AID and SFC experience maximum compatibility, mutual transfers of capabilities and functionalities, etc.;
- we can, of course, introduce here a coefficient that we can call: AI contagion coefficient (CC) which indicates the impact of the introduction of AID on the transition of SFC to AID;
- in principle, it can be considered that a 50% share of AID in the total fixed capital employed by an economic enterprise gives the "signal" of the two simultaneous and opposite processes: the specialization of AID, respectively the de-specialization of labour force – in other words, this would be critical mass of AID in total fixed capital.[xi]

A graphical representation of this AI contagion process is shown in Figure 4.

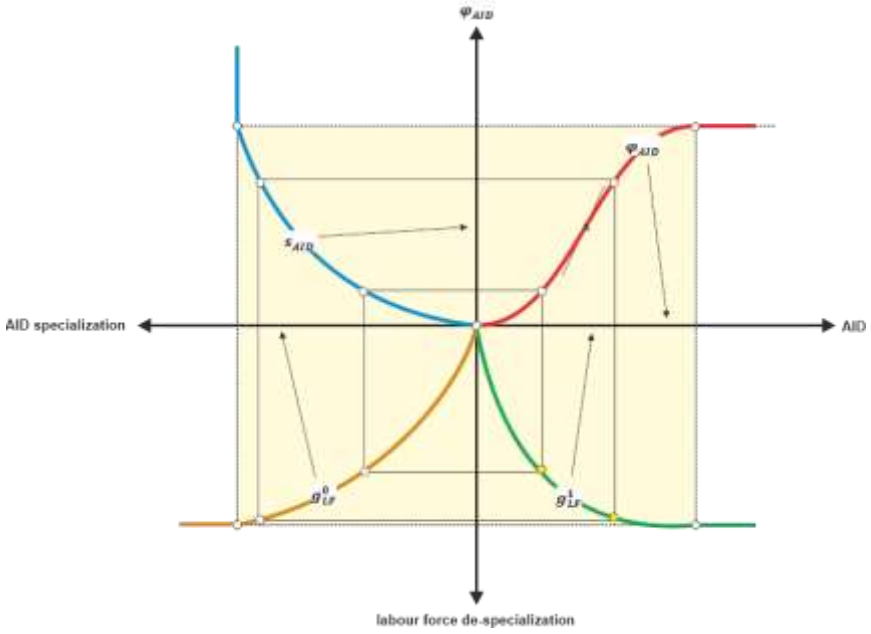

Figure 4. Phenomenology of specialization vs. the phenomenology of de-specialization in the context of AI
(Source: Author's research)

Discussion

- was noted: with FC the fixed capital, with TDF the total of depreciable factors, with LF the labour force, and with φ_{AID} the share of AID in the total of depreciable factors;
- from a formal point of view, we have:

$$TDF = LF + FC$$

$$FC = SFC + AID$$

$$\varphi_{AID} = \frac{AID}{TDF}$$

- ($quadrant\ 1$: $AID - \varphi_{AID}$) the variation of φ_{AID} as a function of the variation of AID, $\varphi_{AID} = \varphi_{AID}(AID)$,, occurs in an adjusted[xii] logarithmic form, with asymptotic ceiling at a level of φ_{AID} above which the FC functionality would begin to decline. This means

that there will always be a need for a certain SFC without which the AID could not function at maximum parameters;

- (*quadrant 2*: φ_{AID} – AID specialization) the variation of the degree of specialization of AID (denoted by s_{AID}) as a function of the variation of φ_{AID}, $s_{AID} = s_{AID}(\varphi_{AID})$, occurs in an adjusted logarithmic form, so that after reaching the ceiling for the value of φ_{AID}, the specialization of AID remains invariant;
- (*quadrant 3*: AID specialization – labor force de-specialization) the variation in the degree of labor de-specialization (denoted by g_{LF}) as a function of the variation in s_{AID}, $g_{LF}^0 = g_{LF}^0(s_{AID})$, occurs according to an adjusted logarithmic curve, which peaks at the turn itself, starting at the very point where s_{AID} is capped;
- (*quadrant 4*: labor force de-specialization – AID) the variation of LF de-specialization as a function of AID variation, $g_{LF}^1 = g_{LF}^1(AID)$, follows an adjusted logarithmic curve that peaks at the level at which g_{LF}^0 capped.

Nota bene: if noted: $x = AID$; $y = \varphi_{AID}$; $z = s_{AID}$; $t^0 = g_{LF}^0$; α: ceiling threshold for y; β: ceiling threshold for z; γ: ceiling threshold for t; $t^1 = g_{FM}^1$ then it can be written succesively:[xiii]

$$y = \frac{\alpha}{1 + e^{-x}}$$

$$z = \ln(y + 1)$$

$$t = \ln(z + 1)$$

$$t^0 = ln[\ln(y + 1) + 1]$$

$$t^1 = ln\left[ln\left(\frac{1 + \alpha + e^{-x}}{1 + e^{-x}}\right) + 1\right]$$

Substitutability and complementarity

The problem of substitutability, respectively complementarity between physical (in fact, fixed physical) capital and labour has always been in the economic field, and their analysis was usually done on the basis of the mathematical properties of the considered production function. In the case of the mixed structure of the fixed capital (SFC, respectively AID), I believe that some changes are expected in this matter, as follows:

(1) regarding *substitutability*: three stages (stages, phases) appear, compared to only one stage in the previous case (absence of AI as a factor of production), namely: (a) a stage of substitutability/substitution between AID and SFC; (b) a stage of formation of the AID-SFC integrated package (let's denote this type of capital with AFC - augmented fixed capital); (c) a substitutability/substitution step of LF with AFC: [xiv]

(a) <u>stage 1</u>: introducing AID into the production function must (at least) preserve the functionality of the productive process, so AID must couple structurally and functionally, in a compatible way, with SFC. The meaning of substitution is, of course, to replace SFC with AID. It can be assumed that, quantitatively, less type AI capital will be required per unit of SFC replaced.[xv] Obviously, a marginal rate of substitution of SFC with AID can be calculated, and this coefficient will be subunit. The question that arises, however, is whether the marginal rate of substitution is increasing or decreasing. We will make a qualitative reasoning:

- it is obvious that, at small shares of AID in FC, the replacement rate of SFC with AID is high, because the difference in effectiveness (and output quality) is overwhelming;
- however, as that share increases, so does the difficulty of replacement, because the readily available, i.e., easier, replaceable "zones" are exploited first; furthermore, as the replacement process continues, AID compatibility with the rest of the SFC becomes increasingly difficult to achieve;
- in my opinion, there is a phenomenon of *rarity* of replacement opportunities, and the coefficient of such a phenomenon can, of course, be calculated.

Figure 5 suggests the graphic image of the marginal rate of replacement of SFC by AID (note: $\lambda_{AI} = \frac{AID}{FC}$ the weight of AID in FC); P^kasymptote-ceiling for λ_{AI}; k_S^{AI}: the coefficient/rate of substitution of SFC with AID; P^λ: the ceiling limit of the share of AID in FC, beyond which the rarity of substitution opportunities becomes the absence of these opportunities).

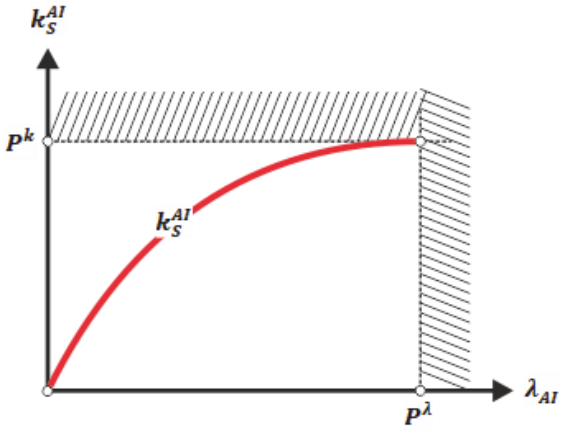

Figure 5. Marginal rate of substitution/replacement of SFC with AID
(Source: Author's research)

(b) stage 2: the formation of the AFC package is a difficult issue and requires, in addition to a purely qualitative examination, a technical, specific one, which we will not comment on in this report. So, we will simply assume that, at some point, we have formed this AFC;[xvi]

(c) stage 3: replacing LF with AFC is a process that does not aim only at simple replacement, but also involves complementarity, therefore this stage will be examined in point (2) below.

(2) regarding *complementarity*: by complementarity is understood a proportion in which an entity is correlated with another entity in a process in which the two entities have a common purpose (or target, as the case may be) – in the case discussed here, it is, of course, about obtaining the output that the economic production function is "called" to produce. What is important in this problem refers to ensuring the functionality of the two correlated entities, functionality that obviously also involves a structural problem. If substitutability occurs "1 to 1", in the case of complementarity, an interval must be accepted within which the proportion of structural correlation between the two entities involved is on a curve, let's say, of indifference from the perspective of preserving functionality. In addition to this difference from substitutability, there is another one: while substitutability aims at effectiveness (more precisely, its increase), complementarity aims at stability: complementarity does not aim at increasing output, but at preserving the ability to obtain the intended output (Dinga *et al*., 2023) . So, we have to examine the complementarity between AFC and LF, more precisely we have to answer the question: by the formation of AFC, does the interval of complementarity (that is, of indifference regarding the functionality of the production function) expand or narrow? Our answer will be formulated on the basis of the suggestion provided by Figure 6, which refers to both the complementarity of AFC-LF and (as stated above – see point (1), (c)) the substitutability of AFC-LF (note: $C_{AFC/LF}$ – complementarity rate between AFC and LF; $S_{AFC/LF}$ – substitutability rate between AFC and LF).

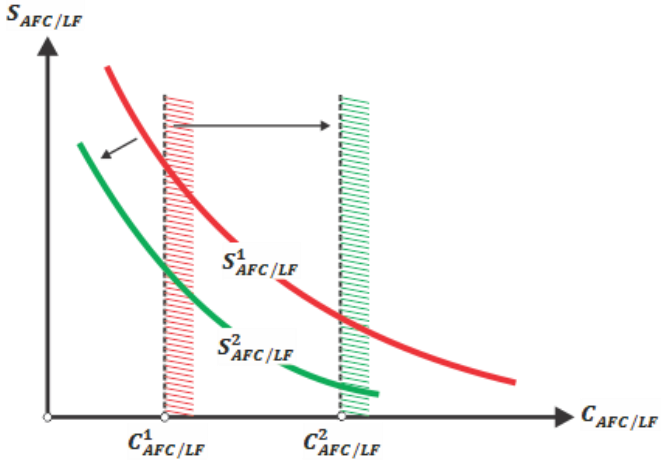

Figure 6. Substitution always occurs under the complementarity restriction
(Source: Author's research)

Discussion

- at the complementarity rate between AFC and LF with the lower value ($C^1_{AFC/LF}$), the (marginal) substitution rate between AFC and LF is relatively high ($S^1_{AFC/LF}$); as the complementarity rate increases (e.g., to $C^2_{AFC/LF}$), the substitution rate decreases (e.g., to $S^2_{AFC/LF}$) because the number of LF dispensing opportunities within the production function decreases;
- the complementarity rate has a certain persistence (rigidity), therefore, once a certain complementarity rate is "established", the substitution rate can only vary to the left (according to Figure 5) of the value of the complementarity rate.

There is the question of the general propensity of the complementarity rate. In our view, the complementarity rate will generally have an asymptotically downward trend towards a floor as the share of AID in AFC increases.

A formalization of the relationship between $C_{AFC/LF}$ and $S_{AFC/LF}$ can be constructed as follows (we denote $C_{AFC/LF}$ with x, as an exogenous variable, and $S_{AFC/LF}$ with y, as an endogenous variable; denote LF by f, and AFC by a):

$$x = \frac{a}{f}$$

$$y = \frac{da}{df}$$

$$\frac{y}{x} = \frac{da}{df} \cdot \frac{f}{a} = \frac{\frac{da}{a}}{\frac{df}{f}} = \frac{r_a}{r_f} = e_{a/f}$$

$$y = e_{a/f} \cdot x$$

where: r_a is the AFC rhythm; r_f is the LF rhythm; $e_{a/f}$ is the elasticity of AFC with respect to LF.

Figure 7 illustrates the linear function $y = y(x)$.

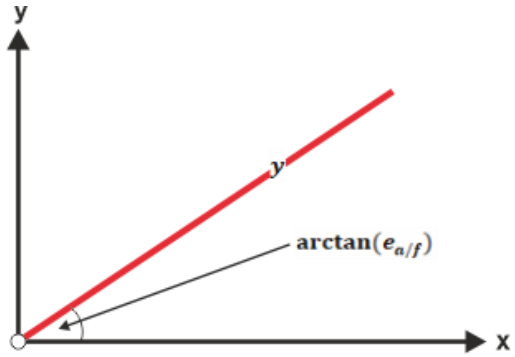

Figure 7. The linear relationship between $S_{AFC/LF}$ (y) and $C_{AFC/LF}$ (x)
(Source: Author's research)

References

Batista, G.E., Wang, X., & Keogh, E.J. (2011). *A Complexity-Invariant Distance Measure for Time Series*, Proceedings of the Eleventh SIAM International Conference on Data Mining, DOI: 10.1137/1.9781611972818.60.

Brynjolfsson, E., Rock, D., & Syverson, C. (2021). The Productivity J-Curve: How Intangibles Complement General Purpose Technologies. *American Economic Journal: Macroeconomics,* 13 (1).

Dinga, E. (2018). On an increasingly yield curve of knowledge. *Studies in Business and Economics*, 13(9). https://ideas.repec.org/a/blg/journl/v13y2018i3p13-25.html.

Dinga, E., Dutca;, M., & Ionescu, G.-M. (2023). *Job security and flexibility: Exploring labour market dynamics.* Palgrave Macmillan – Springer Nature.

Mishra, A., Koopman, R., De Prato, G., Rao, A., Osorio-Rodarte, I., Kim, J., Spatafora, N., Strier, K., & Zaccaria, A. (2023). *AI specialization for pathways of economic diversification*, Scientific Reports, issue 13.

Dinga, E. (2024). *Economic resilience during overlapped crises: Antifragility, sustainability and autopoieticity.* Palgrave Macmillan – Springer Nature. In processing.

Kreuzer, T., Papapetrou, P., & Zdravkovic, J. (2024) – Artificial intelligence in digital twins. A systematic literature review. *Data & Knowledge Engineering*, vol. 151, https://doi.org/10.1016/j.datak.2024.102304.

Wichert, A. (2024). *Quantum artificial intelligence with Qiskit*, Chapman and Hall/CRC. https://www.routledge.com/Quantum-Artificial-Intelligence-with-Qiskit/Wichert/p/book/9781032448978?srsltid=AfmBOooKL2JhzI3VDwR1wCktNKt4gR5TcURt7BHpy-CEcqcP_jknYtHs

[i] I recall that the conceptual distinction between labor force and work led Marx to formulate his theory of capitalism and, in particular, to formulate his theory of the economic exploitation of human being in a capitalist society.

[ii] The established terminology in this matter is as follows: for the physical component the term *hard* is used, and for the informational component the term *software* (normative programs for the functioning of the hard) is used I specify that some elements of normative programming can be integrated directly into the hardware, being complementary to those within the software.

[iii] At least, not for now.

[iv] Something similar occurs in the case of road infrastructure – although those who use that infrastructure (e.g., highways) paid, generically (through income tax paid to the public budget, which financed the infrastructure in question) to build the infrastructure, those users are required to pay a user tax, called a vignette (for Romania: *rovigneta*), from which both the maintenance of that infrastructure and, if necessary,, the implementation of new similar infrastructure are financed.

[v] In my opinion, there is a „law" of total complexity invariance: the internal complexity (generated by the degree of autonomy of the system) and the external complexity (generated by the degree of autonomy of the system's environment) always remains on a given (at least at medium term) indifference curve. About the complexity invariance there are very few approaches in the literature – for example, regarding the time series configuration, see Gustavo E. Batista *et al.* (2011).

[vi] The average is calculated for the case of the non-proportional taxation regime, as an arithmetic average weighted by the number of employees on each tax base range established.

[vii] In the case of the flat income tax rate, the value of P is, of course, exactly the legal value of that rate, expressed as a coefficient.
[viii] Here we have a novelty (more precisely, a "heresy" from standard, textbook economic theory, which accepts the so-called law of diminishing returns, or, equivalently, the law of diminishing marginal utility). The use of knowledge leads to the operation of a law of increasing returns (Dinga, 2018).
[ix] As is known, the minimum limit of complementarity of production factors is equal to the maximum limit of substitutability of production factors.
[x] Here are compelling suggestions for an evolutionary (or, at least, co-adaptive) approach between the kinematics of AID specialization and the kinematics of LF de-specialization. In subsequent interventions, we will also address such a topic of great theoretical and practical relevance.
[xi] From a logical perspective, AID specialization and LF de-specialization are opposite processes, not contradictory processes, i.e., they are opposite but not contradictory with each other – in other words, they are found in relations of contrariety, not relations of contradiction (or inconsistency).
[xii] The adjustment was necessary to remove the infinities.
[xiii] The presented formalism is stylized, purely didactic, non-parametric. It must, of course, be calibrated according to specific contextual elements.
[xiv] The "constitution" of three stages instead of one in the matter of substitutability between physical capital and labor force is intelligible if we take into account a principle (apparently fundamental in the Universe): the interaction between entities (things, properties, relations) is always (i.e., the entities to interact are always chosen) based on the minimum entropic gradient – it is obvious that the entropic gradient between SPC and AID is smaller (in fact, much smaller) than the entropic gradient between AID and LF, respectively between SPC and LF. At the same time, the entropic gradient between CPC and LF is smaller than the entropic gradient between APC and LF but, the second stage having a necessary (obligatory) character, the direct inter-action between SPC and LF becomes ontologically impossible. *Nota bene*: by the way, the fourth industrial revolution, which involves AI, emphasizes the essence of this revolution: the formation of the "package" humans-machines – in my opinion, by machine should be understood the complex noted here with APC.
[xv] The value aspect will, at least in the early stages of AID introduction, be the other way around: AID will be worth more than the SFC it replaces.
[xvi] We only specify that, as it seems to us, the cohesion within a fixed capital structure of the APC type must be greater (or even much greater) than the cohesion within a fixed capital structure of the CFS type.